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The Global Positioning System (GPS) will be an operational military navigation system, but the civil community will have access, with degraded accuracy, to this system. The requirements for information and data about the GPS system for the civil community were investigated. An organizational structure, the Civil GPS Service (CGS), was designated to have overall administrative responsibility and the Civil GPS Information Center (CGIC) to have the responsibility of data and information acquisition and dissemination. The civil users were contacted through a questionaire and a workshop, an interface control document (ICD) was developed between the GPS Operational Control Segment (OCS) and the CGIC, and a system level design was developed for the CGIC. Additional information about GPS was compiled in a bibliography on differential GPS, in a glossary of standard GPS terms, and in a compendium of user equipment.

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Operational Control Segment (OCS)
Operational, Status, and Capability (OPSCAP),
OPSCAP Reporting and Management System (ORMS). (SDW)
interface control document (ICD)
differential GPS

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PREFACE

This is the final report for work conducted by Applied Research Laboratories, The University of Texas at Austin (ARL:UT), under Contract N00024-86-C-6134, Task 12, Project 18, under the technical instruction entitled "Incorporation of the Civilian Community in GPS Operation Capability Reporting System Study". This report is in four volumes. One of the primary efforts associated with this contract was the development of an interface between the U.S. Air Force and the civil community which will allow the civil community access to information regarding the navigation status of the Global Positioning System (GPS). This interface, or point of contact, operated by a civil organization and referred to as the Civil GPS Service (CGS), will serve as a source of information from the GPS Operation Control Segment (OCS) and other sources, and disseminate that information to the civil community. The Civil GPS Information Center (CGIC) will serve as the operational arm of the CGS by providing GPS status information to the civil community.

Volume I. "Determination of the Requirements of the Civil GPS User Community," by Brent A. Renfro.

Volume I summarizes all efforts performed by ARL:UT in meeting the specific tasks described in the contract. These include

(1) establishing a steering committee,

(2) determining needs of GPS civil users,

(3) determining data and data sources which are, or will be, available to the CGS,

(4) conducting a CGS user workshop, and

(5) developing a system design for data distribution.

Volume II. "Appendices to Volume I," by Arnold J. Tucker, Brent A. Renfro, and Jeanne L. Williams.

Volume II, a compendium of appendices, addresses the results of the above tasks in greater detail.

Volume III. "Interface Control Document for the Civil GPS Service Interface to the OPSCAP Reporting and Management System," by Patrick R. Pastor.

Volume III is the interface control document (ICD) defining the requirements related to the transfer of GPS navigation data between the Operational, Status, and Capability (OPSCAP) Reporting and Management System (ORMS) and the CGS.

Volume IV. "Synopsis of Civil GPS User Workshop (22 September 1987)," edited by Arnold J. Tucker.

Volume IV is the synopsis of the GPS Civil User Workshop held on 22 September 1987 in Colorado Springs, Colorado. Included in this synopsis are transcripts of the oral presentations made during the General Session and also summaries from the various discussion groups which were chaired by members of the CGS Steering Committee.

For additional information regarding the CGS, direct queries to the following address.

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Room 8405
Washington, D.C. 20590

I. INTRODUCTION

This final report concerns efforts undertaken by Applied Research Laboratories, The University of Texas at Austin (ARL:UT), for the Global Positioning System (GPS) Joint Program Office (JPO). These efforts were performed under Contract N00024-86-C-6134, Task 12, Project 18.

Many of the efforts associated with this contract concern the development of a distribution channel by which the civil community can be informed of the status of GPS with respect to its usability as a navigation aid. The requirement for this channel is based on the fact that, while current federal radionavigation policy (FRP) establishes that GPS will be available for civil use, the U.S. Air Force (USAF) has no resources available for the support of civil users.

Developing a single interface between USAF and the civil community will allow the civil community access to appropriate information while minimizing the impact on USAF resources. This point of contact, operated by a civil organization and hereafter referred to as the Civil GPS Service (CGS), will serve as a source of information and a point of contact for civil users of GPS. It will accept information from the GPS Operation Control Segment (OCS) and other sources, and disseminate that information to the civil community. It will also serve as a focal point for comments and questions from the civil community regarding GPS.

The tasks associated with this contract include the following.

(1) Establish a CGS steering committee.

(2) Determine needs of GPS civil users.

(3) Determine data and data sources which are (will be) available to CGS.

(4) Conduct a CGS user workshop.

(5) Investigate methods of data distribution and develop system design for this distribution.

(6) Investigate methods by which the CGS might be made self-supporting.

(7) Prepare a dictionary/glossary of standard GPS terms.

(8) Compile a bibliography on differential GPS.

(9) Compile a compendium of user equipment.

Tasks 1-7 are directly associated with development of the CGS while Tasks 8-10 concern issues which may supplement the CGS.

This report is separated into four volumes. A summary of all effort performed on the above tasks and details of the system design are contained in this volume, Vol. I. Except for two items, the complete results of the remaining efforts are contained in a series of appendices in Vol. II. The interface control document describing the interface between the Operational, Status, and Capability (OPSCAP) Reporting and Management System (ORMS) and the CGS (part of task 3) is Vol. III and a synopsis of the Civil GPS User Workshop is Vol. IV.

As currently envisioned, interactions between the CGS, the USAF, and the civil community will occur at several levels. These relationships are diagrammed in Fig. 1. The USAF end of the operational interface to the CGS will be handled by the ORMS. On the CGS end, the ORMS will interface with the Civil GPS Information Center (CGIC). The CGIC will be the operational arm of the CGS concerned with providing GPS status information to the civil community. Operation of the CGIC may be contracted to a private sector organization.

As GPS becomes operational, it is possible that alternate sources of GPS status information may develop. The CGIC will provide a convenient channel for distribution of such information to the civil community.

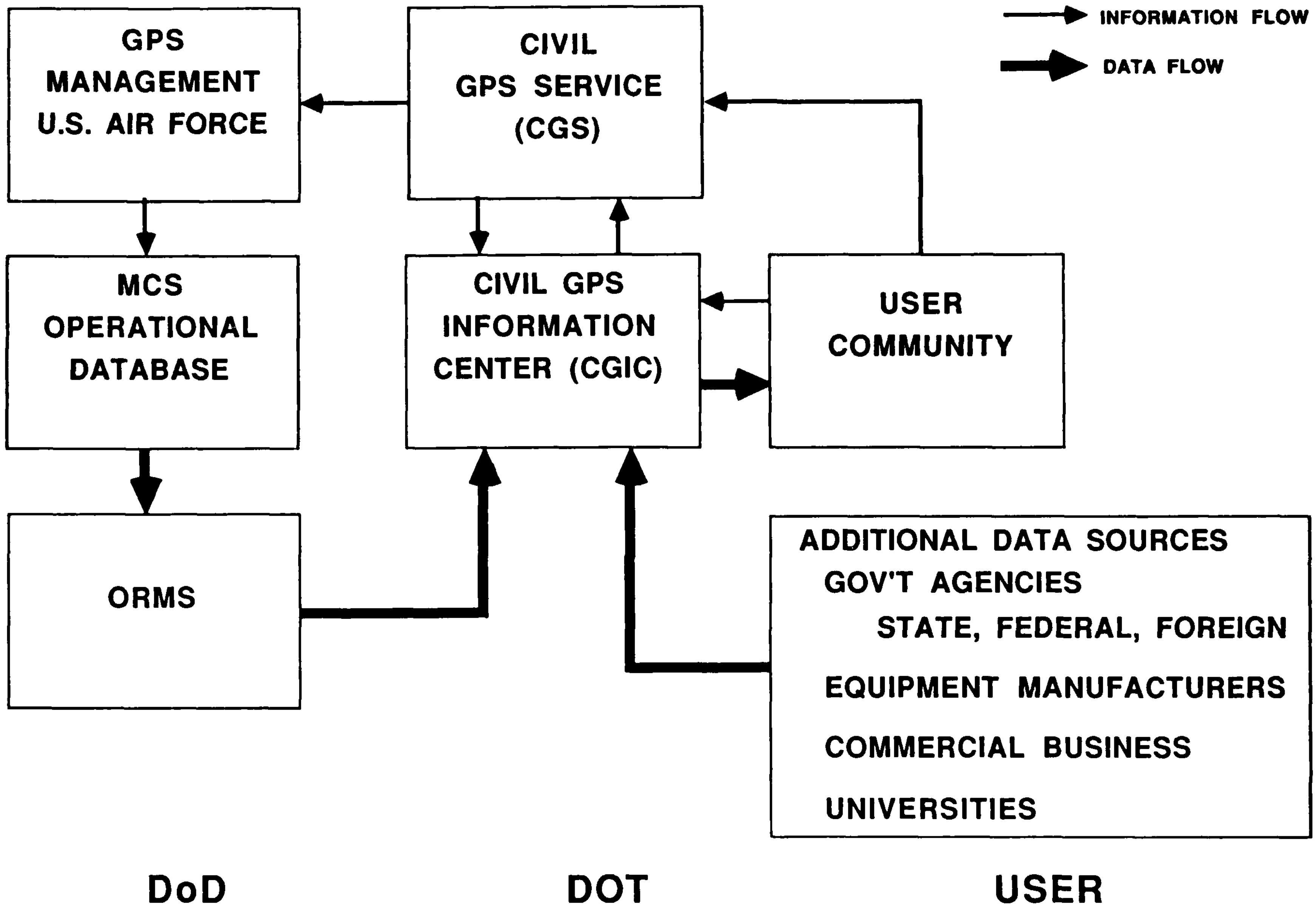

FIGURE 1
CGS ORGANIZATIONAL DIAGRAM

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At the policy level, the CGS will receive feedback from the civil community concerning operation of the CGIC and also serve as a focal point to which the civil community can express their concern to the GPS management in the USAF Space Command.

Much of the effort expended in this project has focused on the design of the CGIC and the interface between the ORMS and the CGIC. However, in performing these tasks, accomplishments were realized beyond those originally anticipated. A few of these are noted in the following paragraphs.

The CGS steering committee, under the chairmanship of DoD/DOT, has been established and should continue to provide assistance to the CGS. The steering committee was first convened on 18 December 1986 and met six times during the period of performance of this contract. The steering committee has provided guidance to ARL:UT efforts in several areas and now stands ready to continue providing such assistance to the eventual designers and developers of the CGS.

Interactions with the Federal Systems Division of IBM (developers of the Military ORMS) not only provided ARL:UT with information required to fulfill its tasking with respect to determination of available data, but also provided IBM with its first end-user input regarding the data types which might be of interest to the end users of the Military ORMS.

An appreciation has been developed of the difference between declaring a system 'available for civil use' and the level of information regarding the status of such a system which must be available if the system is to be a useful tool. This distinction has been a major focus of discussion in the steering committee even though it has rarely been stated in such terms.

In this regard, several items which were determined to be open issues arose during steering committee meetings (see next section). These items need to be readdressed by the CGS as time passes and resolution of these issues becomes possible.

II. STEERING COMMITTEE

In conducting this effort ARL:UT received guidance from the CGS steering committee. This committee consists of representatives from a broad cross-section of government agencies interested in GPS. The committee was formed by the GPS JPO in December 1986 and is now chaired by the U.S. Department of Transportation (DOT). The steering committee charter is contained in Appendix A while Appendix B contains a list of the members of the steering committee and the participants in the steering committee meetings.

During the period of performance of the ARL:UT contract, the steering committee considered several topics which were relevant to the ARL:UT effort. Among those topics were

(1) possible administrative structure(s) for the CGS,
(2) the impact of GPS security policy on the CGS,
(3) liability considerations,
(4) the need for an interim system,
(5) the precise time and time interval (PTTI) community's desire to have at least one GPS SV remain in undegraded operation,
(6) input to DOT design effort, and
(7) names for CGS and CGIC.

In considering possible administrative structures, the steering committee was concerned with finding a sponsor organization which would regard the support of such a service to be within its charter while allowing funding of the CGS to be distributed among several agencies. It was eventually decided that the nature of the CGS required that the organization controlling the CGS be a civil government agency. After an exchange of letters between assistant secretaries of Department of Defense (DoD) and DOT, it was agreed that DOT would take a leading role in the development of the CGS. Currently this is interpreted to mean that DOT will be the coordinating agency responsible for the CGS, but

participation of other agencies will be encouraged. Given the current fiscal restraints in government agencies, participation of other agencies will probably be required if sufficient funding is to be generated.

In discussing the data to be provided to the civil community, the steering committee recognized that there may be information which the civil community desires which will not be available due to security considerations. ARL:UT was directed to concentrate on providing transfer of information regarding the status of GPS with respect to navigation and to avoid requesting data which would reveal the status of the various ground control and monitoring segments or other systems associated with GPS. In cases where a clear determination was not possible, the data were to be included in the system design with the understanding that all requested data were subject to exclusion upon USAF review.

The committee recognized that in attempting to provide GPS status information to the civil community, the CGS may incur liability in the event it fails to provide agreed services. This problem remains unresolved at this time. Government legal departments are studying the ramifications of systems such as the CGS and further discussion in committee is of limited use until such studies have been completed. For the moment, the committee has deemed that the CGS must be operated in a responsible manner, must provide for archiving the information provided, and must consider the traceability of any and all information it decides to provide to the civil users.

The committee determined that there is a need for an interim system. The civil communities' need for information will increase dramatically as the Block II satellites become operational. The ORMS is not planned to be completely operational until the mid-1990 timeframe, though a version of the ORMS, with limited capabilities, should be in place by mid-1989. Therefore, there exists a gap between late 1988 and mid-1990 when the CGS must provide information to users without the benefit of the sort of

system discussed in this report. The committee sees this as an opportunity to deploy a limited system which will allow the CGS to gain experience in the operation of an information distribution system while allowing the end users to indicate the usefulness of the system.

Mr. D. Allan of the National Bureau of Standards (NBS) has proposed that at least one SV be left in undegraded mode to support international time transfer applications. Currently, eight of ten "national" atomic clocks use GPS to compare their time measurements; 62% of the over 250 atomic standards used in computing international atomic time are using GPS for comparison.

During the performance period of this contract, DOT (in particular the Transportation Systems Center), has been working on the design of the administrative structure of the CGS. The steering committee has regularly been updated on this effort and has provided valuable suggestions and comments. As part of this effort, there has been an exchange of letters between DoD and DOT at the undersecretary level, in which DoD invited DOT to be responsible for developing and maintaining the CGS and DOT agreed to take a leading role in such development.

During the steering committee meeting of 27 August 1987, the committee adopted the names "Civil GPS Service" (CGS) and "Civil GPS Information Center" (CGIC). Before this time, the CGS was referred to as the Independent Civil Service (ICS), and the CGIC as the Civil Operational, Status, and Capability Reporting System (Civil OPSCAP). A name change was also initiated by the military; Military OPSCAP is now known as Operational, Status, and Capability (OPSCAP) Reporting and Management System (ORMS).

III. DATA AND DATA SOURCES

During the first meeting of the CGS steering committee, it was suggested that all information the CGS received from the USAF come from the ORMS. The ORMS would have all of the relevant information available as a function of performing its task and the ORMS-CGS interface would provide a one-to-one contact between the military and civilian systems. As an example of the data which would be available by such a channel, Mr. B. Winn of Aerospace, Inc., presented a brief summary of data quantities which the ORMS could provide.

ARL:UT was tasked with starting a tentative list of data quantities and developing an interface control document (ICD) describing the information flow from the ORMS to the CGIC. This ICD is presented in Vol. III of this report.

In developing the ORMS-CGIC interface ARL:UT received support from the Federal System Division of IBM in Gaithersburg, Maryland. This Division developed the Master Control Station (MCS) and is currently developing the ORMS. During several meetings and telephone conversations, IBM provided valuable advice regarding the information available from the OCS, the easiest methods of accessing the data, and the data which would be of most use to users.

Several tradeoffs were considered in designing the ORMS-CGIC ICD. Two major areas where competing constraints led to tradeoffs concerned the amount of data available to the civil community and the distribution of the processing and transmission burdens between the ORMS and the CGIC.

The civil community contains several groups of users. Some of these groups are quite knowledgeable regarding satellite navigation and geodesy and desire to have very complete information regarding GPS status in the broadest sense. Other users, while realizing that the CGIC is not

designed to resolve the integrity issue, would like information to be available as soon as the ORMS has access to the data with minimal delay in passing data through the CGIC.

Both of these desires conflict with GPS data security requirements. In general, only data regarding the performance of GPS with respect to navigation status, and whatever other items a user with a navigation receiver could derive from the signal, will be available through the CGIC. Even within these restrictions, some of these data may be delayed several hours or days before being cleared for distribution. Furthermore, since the ORMS will contain classified data, all transmissions to the CGIC will have to be cleared before transmission. This will probably make it desirable to send data from the ORMS to the CGIC in bursts accumulated over time rather than send the information as it becomes available.

The conflict between processing and transmission comes about because the current design for the CGIC calls for a minimal system which is capable of fulfilling the civil community's needs with a minimum of data processing. Carried to an extreme, this would shift large amounts of data processing to the ORMS and increase the data transmission requirements beyond those which could be reasonably supported. The ICD presented in Vol. III attempts to balance the data processing load on the CGIC against the transmission requirements for the ORMS-CGIC link.

A draft version of the ICD was discussed at the Civil GPS User Workshop (see below) where user community response was solicited. This draft version was also distributed to manufacturers of GPS equipment in order that they might review the ICD for completeness and usefulness of the data set.

IV. GPS CIVIL USER SURVEY

A GPS Civil User Survey was developed for distribution by the civil user community. This survey had two major goals: first, to determine if there was interest in such a system, and second, to determine the opinions of the user community with respect to the data the CGIC would provide and the method(s) by which the data would be distributed.

The survey was developed by ARL:UT and interested civil organizations during the spring of 1987. Feedback from the sponsor agency and the CGS steering committee was instrumental ir determining the final form of the survey. During the summer and fall of 1987 several organizations used this survey to determine the concerns of their members about GPS. The responses of these distributions were made available to ARL:UT for analysis and inclusion in this report. A list of participating organizations is included in Table I.

By the time analysis of the survey began (1 March 1988), 178 survey responses had been received. Responses were received from 16 foreign countries. The survey and an analysis of the responses is included in Appendix C, "Analysis of GPS Civil User Survey" (see Vol. II).

When analysis of the survey began, some organizations were still expecting further responses. If these responses are forwarded to ARL:UT, they will be passed on to the CGS steering committee or whatever organization the committee designates so that these data may be retained for future analysis.

TABLE I

ORGANIZATIONS WHICH PARTICIPATED IN THE
CGS CIVIL USER SURVEY

The Institute of Navigation

Texas Instruments

Airline Electronic Engineering Committee

Technical Support Group (NATO)

NAVSTAR GPS Steering Committee (NATO)

Navigation Subgroup IV (NATO)

Land Survey Division of the Royal Institution of Chartered Surveyors

Institut fur Angewandte Geodasie

Deutsche Gesellschaft fur Ortung und Navigation
(German Institute of Navigation)

Federal Armed Forces Geographic Office

U.S. Naval Observatory Computer Bulletin Board

Yuma Proving Grounds Computer Bulletin Board

V. GPS CIVIL USER WORKSHOP

ARL:UT conducted a GPS Civil User Workshop to inform users regarding the CGS and the CGIC and to gain feedback from the potential end users of the system. The workshop was conducted in Colorado Springs, Colorado, on 22 September 1987 in conjunction with the ION Satellite Division First Technical Meeting. This meeting provided an excellent opportunity to address a group of potential users since the major focus of the meeting was the development and uses of GPS. A synopsis of the workshop is included in Volume IV of this report.

The workshop started with a series of presentations by the GPS JPO, DOT, and ARL:UT. In these presentations, the users were informed of GPS policy with respect to civil use, the current status of DOT planning regarding a Civil GPS System, and the CGIC design being developed by ARL:UT.

Following the presentations, the workshop split into several discussion groups. The discussion groups were organized around GPS applications and were chaired by members of the CGS steering committee.

After the discussion sessions, the workshop adjourned for lunch and reconvened in the afternoon for a closing summary. In the summary session, the discussion group chairmen summarized the discussions which took place in their groups.

While Vol. IV contains more complete details regarding the workshop, the following list summarizes the results of the workshop.

(1) The participants agreed on the need for a means by which civil users can obtain GPS navigation status information.

(2) No significant changes were proposed regarding the data types included in the design of the CGIC. Some minor changes in nomenclature were recommended.

(3) The participants did suggest a number of goals for the CGS beyond the operation of the CGIC. Included in the suggestions were the following.

   (1) CGS should be the civil point of contact and serve as an advocate for civil users.

   (2) CGS should provide a database large enough to handle information on both a general and specific basis, including publishing general GPS information.

   (3) CGS should provide traceability of data and promote standards.

VI. DESIGN OF THE CGIC

To fulfill the CGS goal of distributing information on the status of GPS navigation capability, some means (or several) must exist to distribute that information. For the CGS, the means will be the CGIC. As part of the ARL:UT effort, a system design for the CGIC has been prepared and is presented here.

This design has been evolving for some time, and several organizations have contributed to the design by sharing their experiences. The idea of a CGIC operated by the CGS was proposed at the first steering committee meeting by the DOT. One of the advantages of the concept was that the administration of the CGS could be kept within the government while the operation of the CGIC could be contracted out.

Existing computer bulletin boards at USNO and at the Yuma Proving Grounds distribute GPS status information. While neither of these sites was interested in becoming the CGIC, both sites were very helpful in sharing their experiences and problems.

Early in the study it was discovered that the National Oceanic and Atmospheric Administration (NOAA) office in Boulder, Colorado, operates an information distribution system for solar events. This system, called solar environmental data and distribution system (SELDADS), is responsible for providing a variety of different users with solar information in a timely fashion and uses several different kinds of distribution. The SELDADS administrators and operators were quite willing to share their experiences and much of this design is based on the SELDADS system.

As discussed in the introduction, the CGIC is controlled by the CGS, receives GPS navigation status data from the ORMS, stores and formats these data, and serves as a data distribution point to the users (see

Fig. 1). In addition, there may be other data input sources in the future should the civil community develop reliable sources of information relevant to GPS.

Several products will be produced by the CGIC. The largest effort will be to operate a computer bulletin board which will provide GPS navigation status information to callers in digital form. Additionally, the CGIC will be prepared to answer phone-in questions verbally and respond to written correspondence. Through both the above channels, the CGIC will serve as a focus of civil user feedback to the USAF on operational matters.

Other distribution CGIC services may include the distribution of the following sorts of information:

(1) educational materials on GPS,

(2) archival information on 9-track tape, and

(3) broadcast of GPS navigation status information on WWV.

Number of Users

To design an appropriate system, there must be an estimate of the number of users who will access the system. In forming an estimate of the number of users the following information has been considered:

(1) results of the GPS Civil User Survey,

(2) experience with the TRANSIT system, and

(3) an independent estimate of the future number of civil users.

The results of the survey indicate that there will be at least 100 potential users of the CGIC whenever it becomes available.

The TRANSIT system, a currently operational satellite navigation system, has been used by the civil community since 1968. Since that time, the Navy Astronautics Group has been projecting the use of TRANSIT

every two years. The latest projection (in terms of number of user sets) is shown in Fig. 2. It should be noted that shortly after TRANSIT became available several hundred sets were in use and the number of sets grew dramatically as the cost and size of sets diminished. GPS is more accurate and convenient than TRANSIT, and the advantages of electronic miniaturization are already available to manufacturers of GPS equipment. Therefore, the growth in civil use of GPS may be more dramatic than that in TRANSIT.

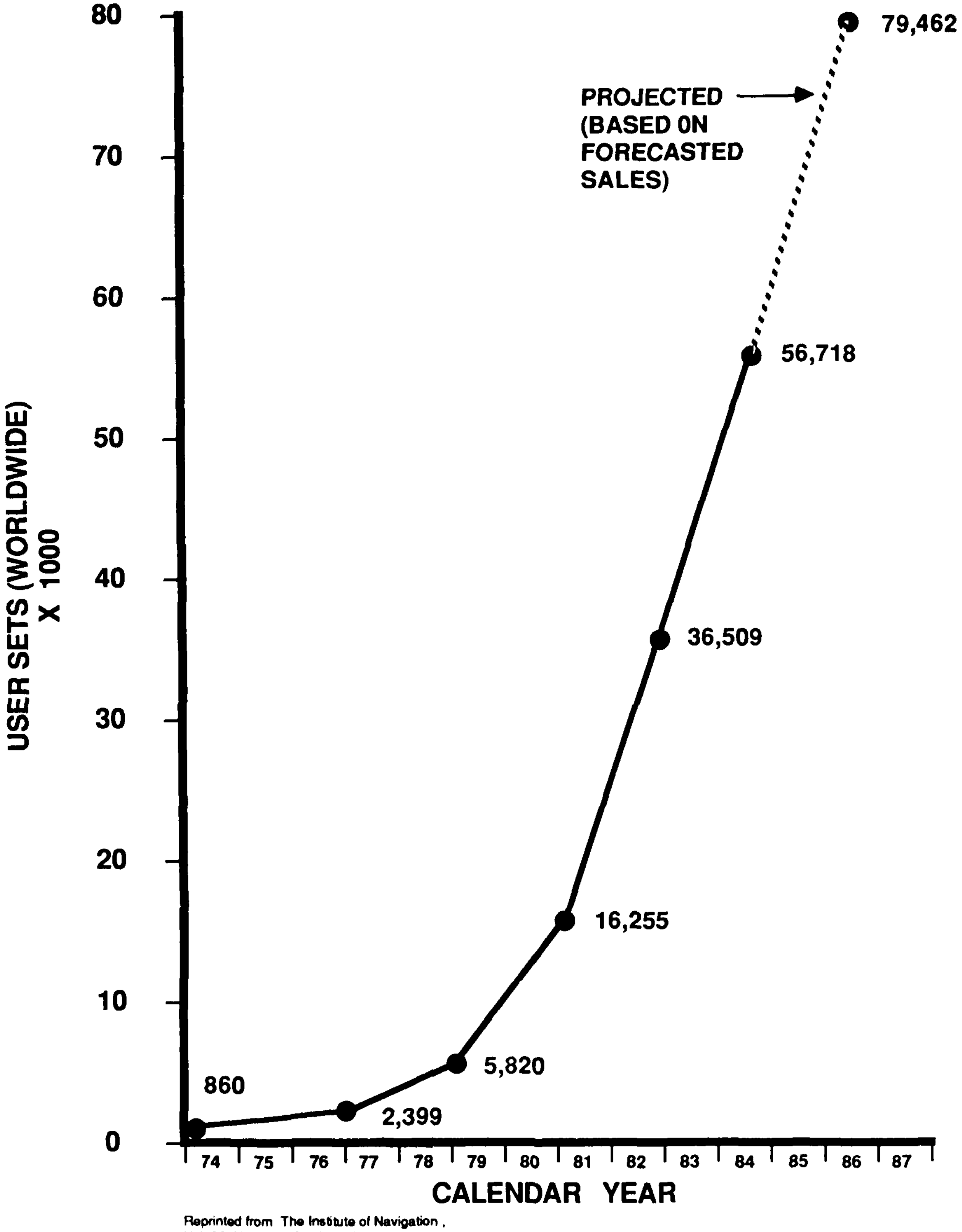
In April 1986, Canadian GPS Associates produced the chart shown as Fig. 3 which illustrates the estimated growth of GPS users over time. By this estimate, there may be more than 10,000 users by the end of 1990.

While each of these sources only yields an estimate of the number of users, it is clear that the potential exists for an explosive growth of the GPS civil user community. Therefore, it is important that the design of the CGIC allow for the initial system to be sufficient to handle the needs of current users and be expandable enough to meet future requirements.

Computer Bulletin Board

The system design for the CGIC computer bulletin board is based on the following assumptions and requirements.

(1) The available data quantities are specified in the ORMS-CGIC ICD. Possible data volumes range from 302 kbytes/day to 2012 kbytes/day.
(2) The system shall be capable of operating 24 hours a day, every day of the year. The system will be manned 16 hours per day, every day of the year.
(3) The system shall be capable of storing data covering several days of transfers from the ORMS.



Reprinted from The Institute of Navigation, Vol. 32, No. 1, Professional file, pg. 97.

FIGURE 2

NAVY NAVIGATION SATELLITE SYSTEM
CURRENT AND PROJECTED USER SETS

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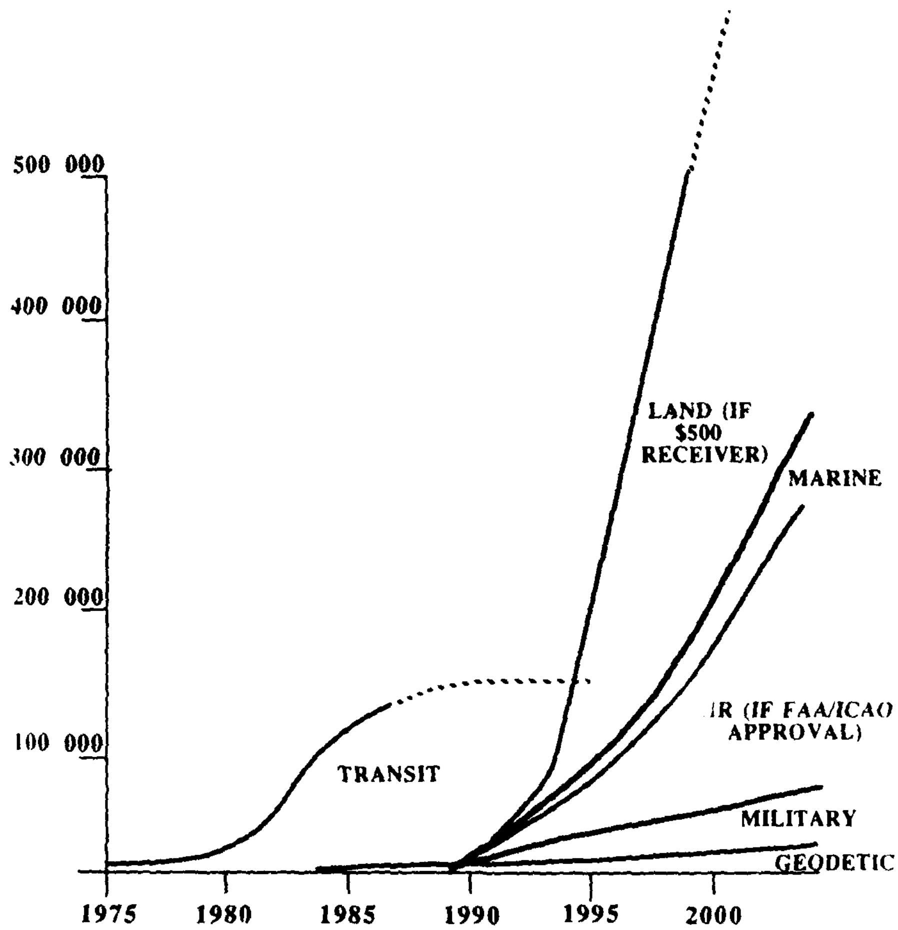

Reprinted from "Guide to GPS Positioning",
Ed. by David E. Wells, Chapter 4.

FIGURE 3
ESTIMATED GROWTH OF GPS USERS

(4) The system shall be capable of handling multiple requests for service at one time. To start with, it should be able to handle at least ten callers at a time.

(5) The system shall always be ready to respond to the ORMS. A second input channel will be available for inputs from other sources.

(6) The system shall be capable of off-line mass storage of archival data.

(7) The system shall allow for the greatest practical ease in growth.

Hardware Design

Figure 4 is a block diagram of the hardware design. The system is built around a MicroVAX II with the following peripherals:

(1) an appropriate hardware interface to the ORMS,

(2) serial multiplexer to connect external input processors to the CGIC,

(3) two high capacity hard disks,

(4) two 9-track tape drives, and

(5) a 12-line auto-answer modem.

The MicroVAX provides a relatively low cost start-up configuration while allowing for upward growth through the entire range of the DEC VAX family. This is important because a great deal of growth may be necessary if the GPS civil user community experiences the growth anticipated. By starting at the bottom of a family of compatible computers, it will be possible to expand the capability of the hardware without rewriting the software package.

The MicroVAX uses either of two popular, well-supported operating systems, VMS or ULTRIX, for which many applications already exist. This

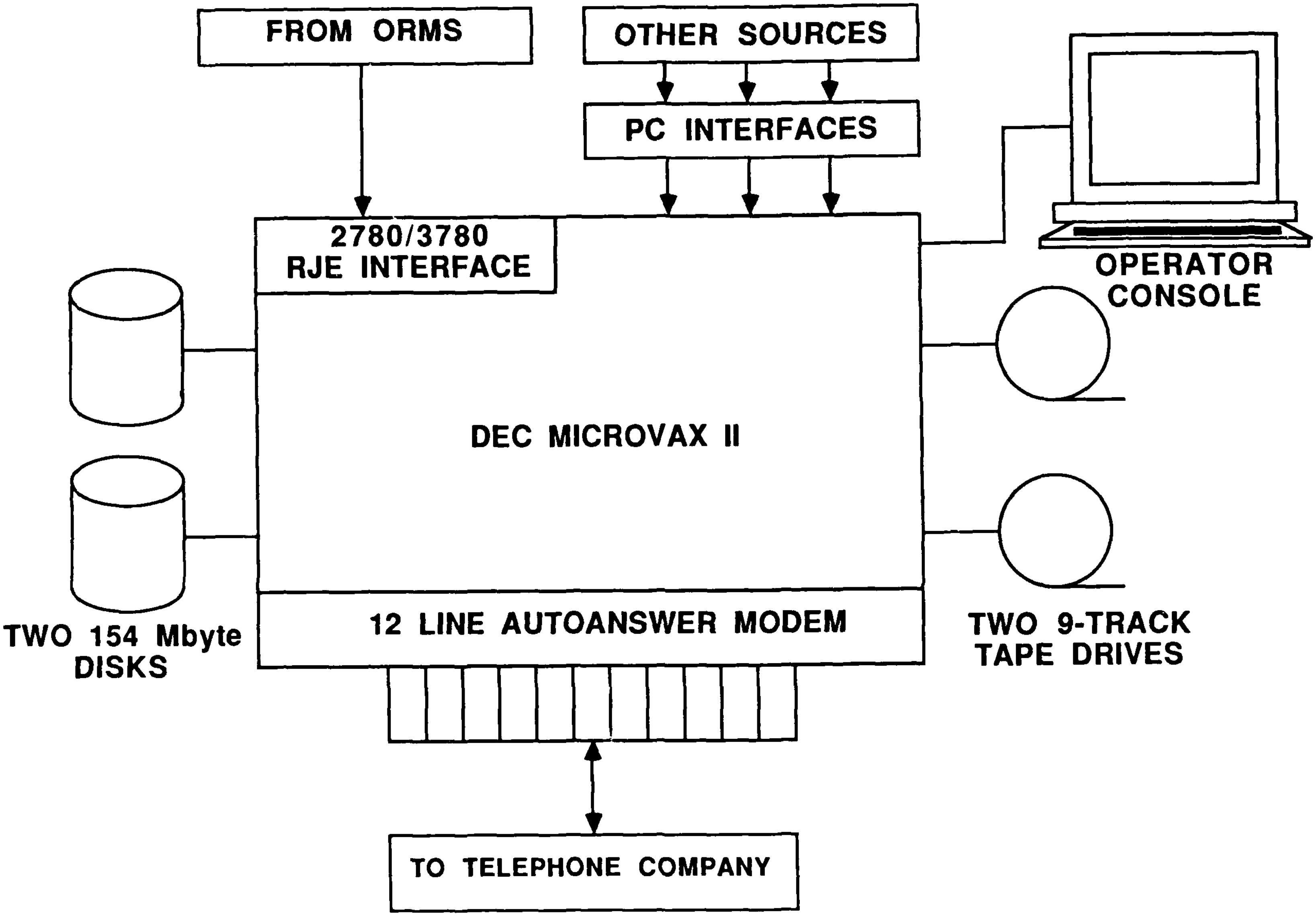

FIGURE 4
DESIGN FOR CIVIL GPS INFORMATION CENTER

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will make it easier to speed development of the system by allowing for the purchase of commercial packages for many of the software items the system requires. Having a standard operating system will also reduce the training time necessary for new operators.

Finally, DEC service agreements are usually readily available in the United States and service agreements can be obtained guaranteeing up to 98% up-time. This will enhance system reliability.

It is important that the CGIC ensure that no user of the CGIC can disturb operation of the ORMS. Therefore, the ORMS-CGIC interface is specified as a RJE (remote job entry) type of interface. In this situation, the ORMS will control all interactions on the ORMS-CGIC line. The ORMS design has not been developed to the point where the preferred method of communication has been determined, but some similar existing interfaces to the OCS use the IBM 3780 protocol specified in this design.

The ORMS interface would connect to a phone line capable of 9600 baud communications and the interface and the phone line would be dedicated to the use of the ORMS. In this fashion, the CGIC is available to receive data from the ORMS any time the CGIC computer is running. Given that the data transfer requirements for the interface range from 302 kbytes/day to 2012 kbytes/day, this interface will only be active for 11-72 min each day.

Other input sources can be handled by routing the input to an IBM PC-compatible computer equipped with an auto-answer modem. (This scheme has been used successfully by the SELDADS system for several years.) As these inputs are not as critical as the ORMS input, the sending party may receive a busy signal when attempting to pass data to the system, but enough PC capacity can be added to the system to permit reasonable access to the data. The PC allows data quality checking and/or reformatting to be performed without adding overhead to the MicroVAX. The PCs also

prevent the direct entry of data into the CGIC from outside sources. Data entering the PCs can be monitored for correctness before being allowed onto the CGIC proper.

While the high capacity hard disks would be sufficient to store the anticipated volume of data, two hard disks are advisable for redundancy. It is assumed that the operating system and the operational software require approximately half of a disk (and that each disk contains a complete, functional set) and that the remainder of the space is available for data storage. This is more than sufficient to provide for 30 days of the maximum data volume of 2012 kbytes/day specified in the ORMS-CGIC ICD. At the minimum data volume of 302 kbytes/day, it will support 240 days of data.

The 9-track tape drives provide archival storage capability and the capacity to copy data for transport to other systems. There are also two drives for redundancy.

The auto-answer modems provide the hardware to allow the remote users to connect to the CGIC. Several manufacturers provide this capability for a MicroVAX. It is strongly recommended that the modems be of a type that plug directly into the chassis of the host computer and that sufficient expansion space be reserved for additional modems. The number of modems in the sample system is based on an assumed worst case estimate of having 100 users each accessing 300 kbytes/day (roughly the size of the minimum transfer/day from the ORMS). Assuming that the users have 2400 baud modems, the data transfer rate will be on the order of 120 bytes/s. At such a rate, each user will require about 45 min to complete their interaction with the CGIC. To serve 100 such users within an eight hour period with a 25% margin, the CGIC will require at least 12 modems. This comes from the following calculation:

$$(100 \text{ users X } .75\text{h/user}) / (8 \text{ hours} * .75) = 12.5,$$

where the answer represents the number of lines which must be available.

Software Design

Based on the above hardware design, the software design can be broken into the following items.

(1) The operating system

(2) The software for handling the ORMS interface

(3) Handling interactions with CGIC users via the modems

(4) Software in PCs for checking/reformatting data

(5) Operator control software for monitoring the system, archiving/de-archiving data, and performing other maintenance functions

(6) Transfer software for moving data from the PCs to the MicroVAX

As stated before, a standard operating system should be used to allow the use of the widest possible set of pre-existing software and experienced personnel. Either VMS or ULTRIX should be acceptable.

The software for handling the ORMS interface is responsible for recognizing requests for service from the ORMS and for proper storage of incoming data. To continue with the example, DEC supports a 2780/3780 protocol emulator for its synchronous interface hardware.

The software which handles interactions with CGIC users must be capable of monitoring the status of the multiple modems, detecting incoming requests, finding the appropriate data, and transmitting that data back to the user. It is envisioned that this software will be in the form of a bulletin board program which allows the user to request subsets of the data which has been transferred to the CGIC from the ORMS. Data sets of interest to many users will be "packaged" by the CGIC to make selection easy. While the bulletin board may allow users to leave messages for the system operator, users should not be allowed to leave messages to each other, and it is important that users not be allowed to

enter data which could change the information in the CGIC via this channel.

The software in the PCs for data quality assurance and data reformatting might best be supplied by the same organization as supplies the data. PCs are widely available and development of these routines by the originator of the data will reduce the need for a programmer at the CGIC and probably result in better interpretation of the data.

The operator control software may consist of one program or many depending on the final design. The major goals are to allow the operator to monitor performance and integrity of the system, maintain a correct disk file structure, and handle the archiving and de-archiving of data to and from the tape devices. This software will also be responsible for the transfer of data from the input handling PCs.

Staffing and Other Considerations

Staffing of the CGIC will require at least three operators and a senior operator. During weekdays, there shall be at least one operator for each 8 hour shift and the senior operator's shift shall overlap the busiest part of the day and cover the change of shift for the operators and the usual time for transfer of periodic data from the ORMS. During weekends, there will be only one person serving as operator at a time.

If it is necessary to allow for the possibility of performing software upgrades to the CGIC after it becomes operational, a programmer will need to be hired to implement these changes. It should also be noted that a separate software development facility should be purchased with similar, but reduced capabilities. The operational CGIC should not be used to develop and/or test software so as to avoid lapses in proper operation.

The CGIC should have access to at least two phone numbers for voice communication. While both can be regular telephones, one number should be reserved for use by calls to/from the ORMS while the other line can be for calls to/from other parties. Once again, this will ensure that information from the ORMS is handled in a timely manner.

Cost/Benefit Considerations

There are several areas of the design where cost/benefit tradeoffs have been made. Among these areas are

(1) hours of operation,
(2) amount of data analysis performed,
(3) number of users supported, and
(4) amount of data kept on line.

The system design calls for the system to be manned 16 hours/day. Expanding operation to 24 hours/day would call for recurring costs on the order of another two man/years per year, or roughly $200,000/year. The system will be available for civil access 24 hours/day, and it should be sufficiently reliable that unmanned operation for eight hours/day would not result in frequent outages of information to the civil community. Therefore, at least in the initial start-up phase, it is felt that 16 hours/day is sufficient.

Another tradeoff area is in the amount of data processing and/or analysis performed by the CGIC. The system design calls for a fairly simple system which forwards data received from outside sources with a minimum of reformatting and no examination or analysis. Starting any level of data processing or analysis would probably require migration to a larger, more capable computer, and would certainly require the hiring of a data analyst. All of the staff discussed above are skilled in system operation and data communications, and would likely not have the scientific background to support processing and analysis of GPS data.

Therefore, supporting a five day a week, 16 hours/day processing and analysis operation would require at least two man years/year.

The number of civil users supported is limited by the capability of the CGIC computer and number of access lines available to the civil community. One of the reasons for picking the DEC VAX family is that there is a computer at the bottom of their price line which has a long line of upwardly compatible machines above it. This should reduce the costs associated with upgrading the system to those costs necessary to purchase and install the necessary hardware upgrades. Costs associated with transporting and/or converting software should be negligible.

The amount of data kept on-line in the CGIC is selected such that most users will have had time to transport data from the field to their main data processing center. If the users put the data through an initial quality check immediately upon arrival, it should still be possible to query the CGIC regarding anomalies and find that the corresponding data are still on-line.

Estimated Cost of CGIC

There are two components to calculating the costs of the CGIC. The first is the non-recurring cost and the second is the recurring cost. The first cost concerns the hardware procurement and the software development necessary to build the system. The second is dominated by the cost of the personnel required to run the system. Table II presents the estimated cost of the hardware outlined in the system design and the software which would be purchased "off-the-shelf". Table III presents the estimated cost of the software development effort associated with the minimal "bulletin board" system specified in the design. These tables taken together are the estimated cost of setting up the CGIC.

TABLE II

ESTIMATED NON-RECURRING COSTS FOR HARDWARE AND SOFTWARE FOR SYSTEM DESIGN

HARDWARE

Qty	Description	Cost (1988 Dollars)
1	Main System (MicroVAX II with 5 Mbytes memory, console, cartridge tape, and dual floppy)	$ 32,075
1	3780 interface	755
12	Phone lines	15,000
2	154 Mbyte disks	14,490
2	1600 bpi 9-track tape drives	25,620
2	Terminals	1,670
	HARDWARE TOTAL	$ 89,610

SOFTWARE

Qty	Description	Cost (1988 Dollars)
1	License for 16 user VMS operating system	$ 13,650
1	VMS media and documentation	1,500
1	License for 2780/3780 protocol emulator	3,045
1	2780/3780 protocol emulator media and documentation	450
1	License for VMS FORTRAN	3,255
1	Media and documentation for VMS FORTRAN	500
1	Database software	16,000
1	Bulletin board software	5,000
	SOFTWARE TOTAL	$ 43,400

TABLE III

ESTIMATED COST OF SOFTWARE DEVELOPMENT EFFORT

TASKS

Establish OCS <-> CGIC link	4 man/months
Construct database to serve provided ICD	6 man/months
Establish database <-> BBS link	6 man/months

MANPOWER (1988 Dollars)

1 Systems Analyst (0.75 myear)		$ 27,000
1 Senior Programmer (0.75 myear)		22,500
	SUBTOTAL	49,500
Administrative Overhead		X 2.5
	TOTAL	$123,750
	GRAND TOTAL	$256,760

Table IV shows the estimated cost of operating the CGIC. The estimated total for setting up the CGIC is $243,000. The recurring cost of operation is estimated at $333,000.

TABLE IV

ESTIMATED COST OF OPERATING CGIC
(RECURRING COSTS PER YEAR)

HARDWARE MAINTENANCE (1988 Dollars)

1	Main System (MicroVAX II with 5 Mbytes memory, console, cartridge tape, and dual floppy)		$ 3,100
1	3780 interface		200
12	Phone lines		2,550
2	154 Mbyte disks		1,500
2	1600 bpi 9-track tape drives		2,150
2	Terminals		300
		HARDWARE TOTAL	$ 9,800

SOFTWARE MAINTENANCE (1988 Dollars)

1	VMS operating system		$ 4,000
1	2780/3780 protocol emulator		800
1	VMS FORTRAN		600
1	Database software		4,000
1	Bulletin board software		500
		SOFTWARE TOTAL	$ 9,900

PERSONNEL (1988 Dollars)
(Assumptions: OCS data only, 12 hours/day operation, 6 days/week)

1	System manager (base salary)		$ 35,000
3	System operators		90,000
		SUBTOTAL	$125,000
	Administrative Overhead		X 2.5
		PERSONNEL TOTAL	$312,500
		GRAND TOTAL	$332,200

8 March 1988

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